Liquefaction Resistance of Silty Soils: 
An Investigation in Christchurch, New Zealand

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Motivation

Liquefaction Field Observations vs. Triggering Predictions

from GEER Report No. 27: Figure 4-5 (b)
Research Goals

- Understand the discrepancy between state-of-practice triggering procedures and post-earthquake observations
- Sample and test silty soils in the laboratory to assess their seismic response and resistance
- Develop “no-liquefaction” case histories for integration in the Next Generation Liquefaction (NGL) dataset
- Provide additional guidance on evaluating the seismic response of silty soils for practicing engineers
Post-Earthquake Reconnaissance

22 February 2010 – Mw 6.2 Christchurch Earthquake
4 September 2010 – Mw 7.1 Darfield Earthquake

Waimakariri River

Moderate – Severe Observed Liquefaction
Minor Observed Liquefaction
No Observed Liquefaction

from the New Zealand Geotechnical Database
Field Investigations

2014: Preliminary Site Characterization & Cyclic Triaxial Testing
- 8 sites – sonic borings, CPTs, crosshole seismic (UT-Austin), high-quality sampling

2016: In-Depth Site Characterization & Detailed Logging
- 3 sites – high-quality sampling, mini-CPTs
Selected Sites

- Site 23 - Riccarton
- Site 33 - Cashmere
- Site 21 - Caulfield
- Site 2 - Gainsborough
- Site 14 - Barrington
- Site 37 - Clarence
S14 - Barrington vs. S23 - Riccarton

S14 (LIQ)  S23 (No LIQ)  S14 (LIQ)  S23 (No LIQ)

DEPTH BELOW GROUND SURFACE (m, BGS)

qc (MPa)  qc (MPa)  Ic (MPa)  Ic (MPa)

est.GWT

DEPTH  BELOW  GROUND  SURFACE  (m, BGS)
High-Quality Sampling

- “Undisturbed” samples
- Cased mud-rotary borings with track rig
  - Side-discharge tri-cone roller bit
- Dames & Moore Sampling Device
  - Hydraulic fixed-piston sampler
  - Thin-walled constant diameter brass sample tubes to reduce disturbance (area ratio = 7.6%)
  - 45 cm sample length (100% recovery)
Cyclic Triaxial Testing

Typical cyclic triaxial test results

Liquefaction triggering criteria:
3% single-amplitude axial strain
5% double-amplitude axial strain
Liquefaction Assessment Comparison

Laboratory data vs.
1) state-of-practice predictions
2) post-earthquake field observations

B&I 2014 selected for preliminary comparisons

- $CRR_{B\&I} \approx 0.16$
- $CRR_{TX,field} \approx 0.19$
- $CSR_{B\&I} \approx 0.38$
Post-Liquefaction Reconsolidation

Non-plastic and Low-plasticity (PI=2) Silt

Non-plastic and Low-plasticity (PI=4-9) Silt
Explaining the “over-prediction”

- Groundwater table fluctuation & “clayey crust”
- Highly stratified subsurface profile
- At-depth suppression of ejecta movement & reconsolidation time
- Angular particles/borderline soil types
- Inherent conservatism in analysis approach

Combination of all the above?

Scale of the problem → macro-scale system response as opposed to element/specimen/particle level response
Depositional Environment

Historical base map and photos from Christchurch: Swamp to City
Thin-Layer Stratigraphy: Detailed Logging from Continuous Sampling

(a) Site 33 - Cashmere
(b) Site 14 - Barrington
Thin-Layer Stratigraphy: Standard CPT vs. Mini-CPT

Site 33 - Cashmere

Site 37 - Clarence

Smearing

Scale of layering
Groundwater Table Effects

Sonic boring (T+T)

Continuous sampling

Crosshole seismic testing (UT-Austin)

Piezometer (NZGD)
Conclusions

- Depositional environment indicates if site conforms to typical clean-sand liquefaction methodologies.
- Appropriate site characterization allows for thorough understanding of in-situ conditions.
- Laboratory testing targets critical layers once site characterization is established; cyclic response of silty soils is nuanced and difficult to broadly categorize.
- Understanding “system” response is key.

Decide if simplified methods are applicable. If not, the above considerations provide information and data to apply engineering judgement and move forward with alternative assessment methods (e.g. numerical modeling).
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